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RUST CANKER DISEASES OF SOUTHERN PINES

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The four principal species of southern pines—longleaf pine (Pinus palustris Mill.), slash pine (P. caribaea Morel.), loblolly pine (P. taeda L.), and shortleaf pine (P. echinata Mill.)—are subject to infection by two native rust fungi, Cronartium cerebrum Hedgc. and Long and C. fusiforme Hedgc. and Hunt. These fungi, which are not known to spread directly from pine to pine, require oaks as an alternate host to complete their life cycles. The galls or cankers caused by these fungi are easily seen on the trunks or limbs of pine seedlings, saplings, and larger trees. The galls or cankers caused by C. cerebrum are round or globelike, while those caused by C. fusiforme are spindle shaped, as illustrated by photograph B.

In late winter and early spring in the Gulf States, these cankers fruit, producing on the surface numerous orange-colored aeciospores, which may be carried by air currents to the young foliage of the several species of scrub oaks common in the region. After the oak leaves have become infected by the aeciospores from the pine, it is possible to see with the unaided eye the fungous structures that appear on the lower side. At first, small round uredia develop, which eject orange-colored uredospores that serve to increase the amount of infection in the oak foliage. Later, in the spring and early summer, from the spots where uredia were produced arise brown hairlike structures known as telia (photograph C), which bear teliospores that germinate and produce sporidia. These sporidia may be carried by air currents for 1,000 feet or more to the growing shoots of pines where they may cause in the pine tissues new infections which later result in galls or cankers. The active period of propagation of these rusts is from early spring to early summer; after that period it is thought that there is little or no increase in pine infection.

Several oak species are known to be infected by these rusts, but further studies are needed to determine the species most susceptible in the Southern States. In this paper, however, the term "scrub oak" is used to cover the oaks often known as "blackjack" or "bluejack" and which are commcommonly found as low bushes or scrubby trees on cut-over pine lands in the Southern States. Quercus marilandica Muench., Q. rubra L., and Q. cinerea Michaux, are common species of this type of oak.

Of the southern pines, longleaf pine is commonly considered the most resistant, and only a few instances of severe rust infection have been noticed in natural reproduction of that species. Shortleaf pine was not severely infected in the areas visited by the writer, but it is reported that this species is quite susceptible to rust fungi in some areas in the South. Both slash and loblolly pines are susceptible to the disease in the nursery, in plantations, and in stands of natural reproduction. The increasing interest in the reforestation of cut-over lands, therefore, as well as the growing interest among foresters and woodsmen in rust diseases, have

resulted in these studies and observations, which indicate the increasing importance of these native diseases, formerly considered of only minor significance in the Gulf States.

Infection in Nurseries

Early in August 1937, abnormal swellings were noticed on the stems of slash pine seedlings in two nurseries in southern Mississippi. By means of microscopic examinations of sections cut from these swellings, it was possible to demonstrate that a rust fungus was present therein. An examination of scrub oak foliage in the vicinity of one nursery made soon after, showed that oak infection was common; Quercus marilandica was the species most severely infected, with Q. rubra ranking second in susceptibility.

In September a survey was made of 10 nurseries growing pine seedlings, in an effort to learn the extent and severity of rust infection in Southern nurseries. Examinations were made in at least 10 different places in each nursery in order to obtain a fair picture of the average amount of disease present; and 100 seedlings were closely inspected at each place, some from the outer part of the seedbed and others from near the center. At the same time notes were taken on the amount of native pine and scrub oak infection near the nursery. From the summary of the data taken on this survey, as given in table 1, it will be seen that numerous pine seedlings are becoming infected in the seedbeds. Both fusiform and cerebroid cankers were found on the seedlings examined, and all infections were on the stems of the diseased plants, as illustrated in photograph A.

Infection in Young Plantations

Seedlings in young pine plantations may become infected from two distinct sources. The first is planting stock infected in the nursery. Several years are required for cankers present on the pine seedlings to develop and produce spores that will increase the amount of rust infection, and since cankers resulting from nursery infection are near the ground line and not ordinarily noticed, it will probably be at least 4 or 5 years before the damage becomes evident. By this time many trees with stem infections will be dead, and cankers resulting from infections that have occurred after planting will become large enough to be noticed easily.

Scattered seedlings with cankers undoubtedly resulting from nursery infection have been found in plantations in Louisiana, Mississippi, and Georgia. Several of these plants were dead or dying; others, alive and apparently vigorous, will probably survive long enough to permit spore production. Scrub oaks were growing in or near all of these plantations, and it is probably only a matter of time before cankers become common. Where 3 percent of the planting stock is diseased when placed in the field, 30 infected trees will be found in every 1,000 seedlings, which is the approximate number planted per acre. If only 5 percent of these survive long enough to produce spores and if scrub oaks are abundant in the vicinity, the stage is set for the production of inoculum sufficient to result in a few years in a severe outbreak of the rust on the trees that were healthy when planted.

The second source of infection is formed by diseased native pines and scrub oaks growing near a plantation. Such trees were quite common in most

Table 1. Prevalence of rust infection on pines in Southern nurseries

Locality and operating agency	Pine species examined	Approximate no. examined	Percent infected	Name and condition of nearby scrub oaks	Name and condition of nearby pines
Woodworth, La.; State Dept. of Conservation	Slash Loblolly	700 300	0 0	No infected oaks noted.	Infected loblolly half a mile from nursery.
Sibley, La.; U.S. Soil Conservation Service	Slash Loblolly	200 900	0 0	No infected oaks noted.	No infected pines noted.
Pollock, La.; U.S. Forest Service	Slash Loblolly	1,100 100	(1 seedling)1/	Infected Q. rubra on all sides of nursery.	Several infected loblolly, four infected longleaf near nursery.
Brooklyn, Miss.; U.S. Forest Service	Slash	3,600	4.5 (0-13)2/	Numerous infected Q. marilandica and some infected Q. rubra near.	Numerous infected loblolly nearby.
Wiggins, Miss.; State Forest and Park Service	Slash	1,000	5.7 (1-12)	Numerous infected Q. marilandica near.	Numerous infected slash and loblolly near.
Livingston, Ala.; State Commission of Forestry	Slash Loblolly	500 600	3.8 (2-5) 3.1 (1-6)	Numerous infected Q. marilandica nearby.	Nursery surrounded by slash and loblolly; many are infected.
Americus, Ga.;U.S. Soil Conservation Service	Slash Loblolly	1,200 1,500	2.0 (0-4) 3.8 (0-8)	Infected Q. marilandica within a few rods of seedbeds.	Infected slash a few rods from seedbeds.
Albany, Ga.; State Department of Natural Resources	Slash	1,300	0.8 (0-3)	Infected scrub oaks (species?) about 1,000 feet from seedbeds.	Infected slash a few rods from seedbeds.
Milton, Fla.; U.S. Farm Security Administration	Slash	1,000	2.8 (0-5)	Infected scrub oaks (species?) nearby.	Infected slash and loblolly nearby.
Olustee, Fla.; State Forest and Park Service	Slash	1,000	0	No infected oaks.	No infected pines.

1/ On December 8, 1937, a small percentage of infected seedlings was found.
2/ Range in percent of infection.

of the planting areas visited in the region and the resulting infections are quite evident (photograph D) in the early years of the plantations, where cankers resulting from field infection and high enough to be easily noticed are found upon the trunk and branches of trees only a few years old. In one 3-year-old slash pine plantation in Mississippi, 13 plants out of 104 in a study plot were infected, and 9 of these are certain to die in a few years. In another slash pine plot in its second growing season, 9 out of 53 trees were infected, all 9 of which will die in a few years. All cankers in these plots are the result of field infections; in both instances oaks were numerous in or near the plantation, and infected native pine trees were growing close by.

Infection in Natural Stands

Stands of natural reproduction, in areas where fire control has allowed slash and loblolly pine seedlings to grow along with scrub oaks, are frequently found to be badly damaged by this disease. In low, swampy country where the oaks are unable to grow, the pine seedlings are free from disease, but on the ridges of higher ground where oaks are growing, the amount of disease increases.

Data on the amount of infection in several plots established for the study of the rust in southern Mississippi and on seedlings and saplings in natural stands in the vicinity of Bogalusa, La., are presented in table 2. All of these plots were located in areas where rust infection was unusually heavy and diseased scrub oaks numerous.

Table 2. Rust infection in young natural pine stands

Pine species	Location	No. examined	Age	Height	Trees diseased	Trees with stem cankers
			Years	Feet	Percent	Percent
Slash	Miss.	73	10	10 - 15	61.6	43.8
Slash	"	183	2	1/2 - 1	10.3	10.3
Loblolly	"	46	12 - 16	23 - 39	65.2	37.0
Loblolly	"	132	12 - 16	20 - 40	65.1	28.0
Slash	La.	64	-	2 - 6	20.3	7.8
Slash	"	73	-	3 - 10	24.6	17.8
Slash	"	200	-	15 - 25	4.0	0.5
Loblolly	"	71	-	10 - 20	80.2	29.6
Loblolly, slash, and shortleaf	"	400 (approx.)	-	2 - 20	6.5	0.0

A . Rust cankers on stems of 1 - 0 slash pine nursery stock. B. Typical mature fusiform gall with aecia showing on surface. C. Telia on Quercus imbricaria. This unusually heavy infection is the result of inoculation. D. Stem and branch cankers on 7-year-old slash pines in plantation in southeastern Louisiana. Persistence of the infected lateral branches and proliferation of branches are characteristic symptoms of rust infections. (B and C photographed by G. G. Hedgcock.)

The ultimate effect of these cankers upon stands of natural reproduction and plantations will depend upon a number of factors such as the age of the stand, the number of fruiting cankers, the number and species of scrub oaks present, and the density of the stand. Observations and examinations show that many diseased trees will probably die before they reach commercial maturity or will break over where the cankers occur. This is especially true if the infection takes place when the tree is young. The death of infected trees may tend to thin out a dense stand, with little harm or even with benefit, but on the other hand so many desirable trees may be lost that the stand will be greatly reduced in value. This loss will be especially important where pulpwood and other intermediate forest products are to be taken from a stand of timber, and for the study of problems of this nature plots have been established both in plantations and in areas of natural reproduction.

Effect of Current Forest Management Practices on Infection

For many years, both before and after removal of the virgin timber, fires burned over longleaf pine lands. During the last 13 years, since the Federal Government has cooperated with timberland owners and with the States, mainly as a result of the enactment of the Clarke-McNary Law, the fire problem on thousands of acres in the commercial longleaf pine region is being met successfully.

It is a matter of common observation that the commercial range of longleaf pine has been reduced by the other species of pines, particularly loblolly and slash. Without discussing all of the reasons for this change in forest type, it is believed that the exclusion of fire favors the regeneration of loblolly and slash pines at the expense of longleaf, and that the partial replacement of longleaf by slash pine in the naval-stores region of the United States is largely a result of the exclusion of forest fires from much of this territory during the last decade. Also artificial reforestation of denuded or understocked longleaf pineland has advanced rapidly, owing to a growing appreciation of the fact that the Gulf region is particularly favored by environmental and economic conditions for profitable timber growing; and the increasing popularity of slash pine for this reforestation has resulted in its use for planting beyond its natural range and on typical longleaf sites.

As a result, therefore, of artificial regeneration and the exclusion of fire on areas of natural reproduction, many areas that once carried commercial stands of longleaf pine are now covered with young forests of loblolly or slash. Since the two native rust fungi, Cronartium cerebrum and C. fusiforme, are normally endemic on loblolly and slash pines over most of the range of longleaf, with the extension of stands of rust-susceptible pines to areas of denuded or understocked longleaf land, where numerous scrub oaks were growing, conditions were made almost ideal for rust epidemics.

As each series of rust cankers matures and begins to produce spores, the number of infected oaks is increased, which results in a still greater amount of pine infection in an ever-widening circle. Many stands of slash and loblolly pine that became established soon after an area was cut over have little rust infection today, but younger stands are much more severely diseased; and the amount of disease present is increasing from year to year, as is shown by the numerous cankers that have developed in the past few years on the young seedlings and in the crowns of older trees formerly free from disease.

There are several plantations of slash and loblolly which are now old enough to illustrate the rapid increase in rust infection in the last few years. One such plantation established on cut-over pine land in 1925-26 showed a low percent of infection in the first 8 years of its history, during which time only 3 to 4 percent of the trees became infected. Three years later, however, a brief survey in the same area showed that among the 305 trees (of both species) examined, 37 percent were infected, while 10 percent had trunk infections which may cause them to break over and be lost. It is quite evident that most of the cankers now present in this stand are only a few years old and have not yet produced spores. Many of these new infections in the crowns are on the stem or on branches a short distance from the trunk.

Infection is even more severe in several slash plantations established near the older ones in 1930-31. A survey made in March 1937 in one plantation showed that 35 percent of the trees were infected and that 17 percent had cankers which would render the trees worthless in a few years. A study plot containing 75 trees was established in August of the same year, and in this plot 56 percent of the trees were infected and 23 percent so badly diseased that they are worthless. A survey made in October in another plantation of approximately the same age revealed that here 40 percent of the trees are now infected, while 25 percent are worthless because of cankers on the trunk.

In both the older and younger plantations, the fact that most of the cankers were young and had not yet fruited indicates that the number of infections is increasing rapidly. It seems probable that the higher percentage of disease in the younger plantations is largely due to the fact that the amount of oak infection has been heavier during the life of the plantation than it was in the early years of the older plantations, which in turn is probably due to the increasing number of fruiting cankers on the older pines. There is some evidence that nursery infection is responsible for some of the older cankers in the stand, and it is also probable that some of these older cankers are the result of spores produced by cankers on trees left after the area was cut over. It seems quite possible, therefore, that this rapid increase in the number of cankers and severe injury to the stand will be repeated in other young pine stands where scrub oaks are present near diseased pines.

In several of the plots established for the study of the rust canker disease, the trees, which are at least 7 years old, have cankers of several ages. Because it is very difficult to determine the age of these cankers, the 320 cankers measured in these plots have been divided into 3 general classes which include both species of rust fungi and both stem and trunk infections. The first class, which includes cankers estimated to be less than 3 years old, contains 60 percent of the 320 infections. The second class, including cankers estimated to be from 3 to 5 years old, contains 34 percent. The last class, which includes those infections estimated to be more than 5 years old, contains only 6 percent of the total number of cankers studied in these plots. These figures show that in the last 5 years there has been a great increase in the amount of rust infection, some of which was probably due to the growth of the host trees; in other words, there are now more limbs to be infected than existed a few years ago. It is also probable that a large amount of this infection was due to the increasing number of spore-producing cankers in and about these plots. As more and more cankers produce spores, oak infection has also doubtless increased, while this increased amount of oak infection serves to cause more pine infection, and so on.

Control Measures

Although nursery infection can probably be minimized by the complete eradication of all scrub oaks within 1,300 feet of the nursery, the removal of all pine cankers within this zone would also be desirable. Since heavy concentrations of infected oaks or of pine cankers at even greater distances may result in considerable infection, their removal would supply a further safeguard. Cutting back the oaks, which results in the growth of numerous sprouts with many leaves highly susceptible to rust infection, must not be considered as a means of eradication; this can be effected by the use of tree poisons, girdling,[1/] or by pulling with tractors. Where planting stock is infected in the nursery, it should be carefully culled before being sent to the field for planting in order to eliminate all seedlings with abnormal swellings on the stems.

Infection in the field could be prevented by planting only on sites free from scrub oaks or by planting disease-free stock on sites from which all rust cankers have been removed. The use on diseased areas infested with scrub oaks of species known to be resistant to the rust canker is probably the best control method for most areas in the Southern States; under such conditions longleaf is probably the most desirable species.

There is probably little that can be done to prevent or control these diseases in natural stands in areas where scrub oaks are common. Until more is known as to the ultimate effect of the rusts, in areas where scrub oaks are numerous it would seem advisable to favor longleaf (or perhaps shortleaf) pine rather than pure stands of slash or loblolly.

Summary and Conclusions

From a survey of nurseries growing southern pines for reforestation, it has been learned that slash and loblolly seedlings are being infected in the seedbed with Cronartium rust. Nursery infection is more important in localities with large numbers of diseased pines and infected oaks about the nursery than in areas where natural infection is not abundant. Observations indicate that where scrub oaks are not present in the area about a nursery, the pine seedlings remain uninfected.

Observations made in plantations and in natural stands of slash and loblolly pines also demonstrate the importance of rust infection in the field, and data presented show how the disease tends to increase in severity from year to year.

By artificial regeneration and by natural means many commercial stands of longleaf have now been superseded by young forests of loblolly and slash. Also it is recognized that complete fire protection has served to favor the natural regeneration of these pines at the expense of longleaf. Extension of these susceptible species of pine to areas where scrub oak is abundant has produced conditions favoring rust epidemics, and heavy losses in some of the young forests are threatened by these native diseases through planting diseased nursery stock and through natural infection in areas where scrub oaks are abundant.

Several control measures for nurseries and plantations are suggested,

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1/ Bull, Henry, and Chapman, R. A. 1935. Killing Undesirable Hardwoods in Southern Forests. Occasional Paper No. 50. Southern Forest Exp. Sta., New Orleans, La.